ACOUSTIC SIGNAL TRANSMISSION COUPLANTS AND COUPLING MEDIUMS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This patent document claims the benefit of priority of U.S. Provisional Patent Application No. 62/120,839, filed on February 25, 2015, and U.S Provisional Patent Application No. 62/174,999, filed on June 12, 2015. The entire contents of the before-mentioned patent applications are incorporated by reference as part of the disclosure of this document.

TECHNICAL FIELD

[0002] This patent document relates to systems, devices, and processes for acoustic energy diagnostics and therapies.

BACKGROUND

[0003] Acoustic imaging is an imaging modality that employs the properties of sound waves traveling through a medium to render a visual image. High frequency acoustic imaging has been used as an imaging modality for decades in a variety of biomedical fields to view internal structures and functions of animals and humans. High frequency acoustic waves used in biomedical imaging may operate in different frequencies, e.g., between 1 and 20 MHz, or even higher frequencies, and are often termed ultrasound waves. Some factors, including inadequate spatial resolution and tissue differentiation, can lead to less than desirable image quality using conventional techniques of ultrasound imaging, which can limit its use for many clinical indications or applications.

SUMMARY

[0004] Techniques, systems, and devices are disclosed for coupling acoustic signal transducers to body structures for transmitting and receiving acoustic signals in ultrasound imaging, range-Doppler measurements, and therapies.

[0004a] In one aspect, there is provided a couplant device for transmission of acoustic energy between transducers and a target, comprising: an array of transducer elements to transmit acoustic signals toward a target volume and to receive returned acoustic signals that return from at least part of the target volume; a housing body including a curved section on which the array

of transducer elements are arranged; and an acoustic coupling component including a single hydrogel material that couples to each of the transducer elements of the array, the acoustic coupling component operable to conduct the acoustic signals between a transducer element disposed in the housing body and a receiving medium in contact with the acoustic coupling component to propagate the acoustic signals toward the target volume, wherein the hydrogel material of the acoustic coupling component is capable to directly contact and conform to the receiving medium and to the transducer element such that the acoustic coupling component provides an acoustic signal transmission path between the receiving medium and the array of transducer elements to obtain a substantial acoustic impedance matching between the receiving medium and the transducer element.

[0004b] In another aspect, there is provided an acoustic waveform system, comprising: a waveform generation unit comprising one or more waveform synthesizers coupled to a waveform generator, wherein the waveform generation unit synthesizes a composite waveform comprising a plurality of individual orthogonal coded waveforms corresponding to different frequency bands that are generated by the one or more waveform synthesizers according to waveform information provided by the waveform generator, wherein the individual orthogonal coded waveforms are mutually orthogonal to each other and correspond to different frequency bands, such that each of the individual orthogonal coded waveforms includes a unique frequency with a corresponding phase; an acoustic signal transmission couplant including: a housing body including a curved section on which transducer elements are arranged, an array of transducer elements to transmit acoustic waveforms corresponding to the individual orthogonal coded waveforms toward a target volume and to receive returned acoustic waveforms that return from at least part of the target volume, and an acoustic coupling component including a single hydrogel material that couples to each of the transducer elements of the array, the acoustic coupling component operable to conduct the acoustic waveforms between a transducer element disposed on the housing body and a receiving medium in contact with the acoustic coupling component, wherein the hydrogel material of the acoustic coupling component is capable of directly contacting and conforming to the receiving medium and to the transducer element such that the acoustic coupling component provides an acoustic signal transmission path between the receiving medium and the array of transducer elements to obtain a substantial acoustic impedance matching between the receiving medium and the transducer element; a multiplexing

unit in communication with the array of transducer elements to select one or more transducing elements of the array to transduce the individual orthogonal coded waveforms into the corresponding acoustic waveforms, and to select one or more transducing elements of the array to receive the returned acoustic waveforms; and a controller unit in communication with the waveform generation unit and the multiplexing unit and comprising a processing unit to process the received returned acoustic waveforms to produce a data set including information of at least part of the target volume.

[0005] In one embodiment, a couplant device of the disclosed technology for transmission of acoustic energy between transducers and a target includes a housing body structured to present an array of transducer elements on a curved section (e.g., curved lip) of the housing body (e.g., such as a semicircular or a circular portion that exposes the transducer elements of the array on a

CLAIMS

What is claimed is:

1. A couplant device for transmission of acoustic energy between transducers and a target, comprising:

an array of transducer elements to transmit acoustic signals toward a target volume and to receive returned acoustic signals that return from at least part of the target volume;

a housing body including a curved section on which the array of transducer elements are arranged; and

an acoustic coupling component including a single hydrogel material that couples to each of the transducer elements of the array, the acoustic coupling component operable to conduct the acoustic signals between a transducer element disposed in the housing body and a receiving medium in contact with the acoustic coupling component to propagate the acoustic signals toward the target volume,

wherein the hydrogel material of the acoustic coupling component is capable to directly contact and conform to the receiving medium and to the transducer element such that the acoustic coupling component provides an acoustic signal transmission path between the receiving medium and the array of transducer elements to obtain a substantial acoustic impedance matching between the receiving medium and the transducer element.

2. The device of claim 1, further comprising:

a flexible bracket coupled to and capable of moving with respect to the housing body, wherein the acoustic coupling component is attached to the flexible bracket.

3. The device of claim 1, wherein the hydrogel material includes polyvinyl alcohol (PVA).

4. The device of claim 1, wherein the hydrogel material includes polyacrylamide (PAA).

5. The device of claim 4, wherein the hydrogel material includes alginate.

6. The device of claim 1, wherein the acoustic coupling component includes an outer lining at least partially enclosing the hydrogel material.

7. The device of claim 1, wherein the acoustic coupling component is operable to propagate the acoustic signals with an attenuation factor of 0.1 dB/MHz2•cm or less, or with an impedance of 1.5 MRayls or less.

8. The device of claim 1, wherein the acoustic coupling component is capable to undergo a %elongation of 1000% or greater, or includes a shear modulus of 1 MPa.

9. The device of claim 1, wherein the target volume includes a biological structure of a living subject and the receiving medium includes an anatomical structure of the living subject.

10. The device of claim 9, wherein the curved section of the housing body includes a curvature to facilitate complete contact with the anatomical structure, such that the acoustic coupling component is in direct contact with skin of the anatomical structure.

11. The device of claim 10, wherein the anatomical structure includes hair on exterior of the skin.

12. The device of claim 9, wherein the anatomical structure includes a breast, an arm, a leg, a neck including the throat, a knee joint, a hip joint, an ankle joint, an elbow joint, a shoulder joint, an abdomen, or a chest, or a head.

13. The device of claim 9, wherein the biological structure includes a cancerous or noncancerous tumor, an internal lesion, a connective tissue sprain, a tissue tear, or a bone.

14. The device of claim 9, wherein the subject includes a human or a non-human animal.

15. The device of claim 1, wherein the curved section of the housing body includes a semicircular geometry.

16. The device of claim 1, wherein the curved section of the housing body includes a 360° circular geometry, and the array of transducer elements is arranged along the 360° circular section of the housing body.

17. The device of claim 16, wherein the 360° circular section of the housing body and the acoustic coupling component provide a curvature to facilitate complete contact around an anatomical structure of a living subject, and wherein the device is operable to receive the returned acoustic signals from the target volume such that an acoustic imaging system in data communication with the device is able to produce a 360° image of the target volume.

18. The device of claim 1, further comprising:

a multiplexing unit contained in an interior compartment of the housing body and in communication with the array of transducer elements to select one or more transducing elements of the array to transmit individual acoustic waveforms, and to select one or more transducing elements of the array to receive the returned acoustic waveforms.

19. An acoustic waveform system, comprising:

a waveform generation unit comprising one or more waveform synthesizers coupled to a waveform generator, wherein the waveform generation unit synthesizes a composite waveform comprising a plurality of individual orthogonal coded waveforms corresponding to different frequency bands that are generated by the one or more waveform synthesizers according to waveform information provided by the waveform generator, wherein the individual orthogonal coded waveforms are mutually orthogonal to each other and correspond to different frequency bands, such that each of the individual orthogonal coded waveforms includes a unique frequency with a corresponding phase;

an acoustic signal transmission couplant including:

a housing body including a curved section on which transducer elements are arranged,

an array of transducer elements to transmit acoustic waveforms corresponding to the individual orthogonal coded waveforms toward a target volume and to receive returned acoustic waveforms that return from at least part of the target volume, and

an acoustic coupling component including a single hydrogel material that couples to each of the transducer elements of the array, the acoustic coupling component operable to conduct the acoustic waveforms between a transducer element disposed on the housing body and a receiving medium in contact with the acoustic coupling component, wherein the hydrogel material of the acoustic coupling component is capable of directly contacting and conforming to the receiving medium and to the transducer element such that the acoustic coupling component provides an acoustic signal transmission path between the receiving medium and the array of transducer elements to obtain a substantial acoustic impedance matching between the receiving medium and the transducer element;

a multiplexing unit in communication with the array of transducer elements to select one or more transducing elements of the array to transduce the individual orthogonal coded waveforms into the corresponding acoustic waveforms, and to select one or more transducing elements of the array to receive the returned acoustic waveforms; and

a controller unit in communication with the waveform generation unit and the multiplexing unit and comprising a processing unit to process the received returned acoustic waveforms to produce a data set including information of at least part of the target volume.

20. The system of claim 19, further comprising:

an array of analog to digital (A/D) converters to convert the received returned acoustic waveforms received by the array of transducer elements of the acoustic signal transmission couplant from analog format to digital format as a received composite waveform that includes information of at least part of the target volume.

21. The system of claim 19, further comprising:

a user interface unit in communication with the controller unit.

22. The system of claim 19, wherein the produced data set includes an image of at least part of the target volume.

23. The system of claim 19, wherein the acoustic signal transmission couplant includes a flexible bracket coupled to and capable of moving with respect to the housing body, wherein the acoustic coupling component is attached to the flexible bracket.

24. The system of claim 23, wherein the hydrogel material includes at least one of polyvinyl alcohol (PVA), polyacrylamide (PAA), or PAA with alginate.

25. The system of claim 19, wherein the curved section of the housing body of the acoustic signal transmission couplant includes a semicircular geometry, or the curved section of the housing body of the acoustic signal transmission couplant includes a 360° circular geometry such that the array of transducer elements are arranged along the 360° circular section of the housing body.

26. The system of claim 25, wherein the 360° circular section of the housing body and the acoustic coupling component provide a curvature to facilitate complete contact around an anatomical structure of a living subject, and wherein the device is operable to receive the returned acoustic waveforms from the target volume such that the system is able to produce a 360° image of the target volume.